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Reply to the comment on the paper "Lago Mare and the Messinian Salinity Crisis: Evidence from the Alboran Sea (S. Spain) by Do Couto et al. (2014) Marine and Petroleum Geology 52 (57–76)" authored by Serrano and Guerra-Merchán

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Abstract

The marine context of the Lago Mare deposit near Malaga has received agreement as well as its ascription to the third Lago Mare event of Clauzon et al. (2005). This deposit is not a "transitional unit towards normal marine conditions" but followed the marine reflooding of the Mediterranean Basin, allowing the connection with the Dacic Basin (Eastern Paratethys). We show that this Lago Mare event did not result from a climatic change leading to a dilution episode but from a high sea-level connection. Different interpretations on the respective effects of tectonics and eustatism on the sedimentary archives linked to the Messinian Salinity Crisis (MSC) are once more debated. They depend on (1) the duration assigned to the MSC and its subdivisions, (2) the amplitude of the successive sea level variations, and at last (3) the dimensional (local or regional) view of the MSC. Such discrepancies concern subsidiary matters which cannot mask first order facts and progresses in their knowledge.

Key-words: Alboran Sea, Post-Messinian Crisis reflooding, Lago Mare, Mediterranean – Paratethys high sea-level connection

We welcome the opportunity to answer this comment that mixes up first order and secondary aspects of the Messinian Salinity Crisis which are worth distinguishing. Accordingly, our reply first concerns the new context of the Malaga Lago Mare which is partly accepted by Serrano and Guerra-Merchán. Then, we return to the old debate on the respective impact of tectonic activity and sea-level changes during and just after the Messinian Salinity Crisis (MSC) which, at last, affect the interpretation of the Messinian – Zanclean archives.

1. Marine context of the Malaga Lago Mare deposition

As a major conclusion of the paper by Do Couto et al. (2014), we showed that the Lago Mare (LM) of the Malaga area has been deposited during a marine context of high sea level that is agreed by Serrano and Guerra-Merchán. It corresponds to the LM 3 event (Clauzon et al., 2005) that is not questioned by these authors. We interpret this event as the consequence of the fast marine reflooding of the Mediterranean Basin which resulted from the collapse of the Gibraltar sill (Garcia-Castellanos et al., 2009) and rapidly allowed the connection with the Paratethyan Dacic Basin (Bache et al., 2012). This is the only way to explain the large amounts of mixed Atlantic and Paratethyan fossils (calcareous nannofossils, foraminifers, molluscs, and dinoflagellate cysts on the one hand, ostracods, molluscs and dinoflagellate cysts on the other hand; Guerra-Merchán et al., 2010; Do Couto et al., 2014). Serrano and Guerra-Merchán interpret the marine character of the LM 3 episode as resulting from initiated brief and repeated oceanic overflows into a brackish Mediterranean Basin. On contrary, our palaeobiological data show that this LM 3 episode results from only one event, the massive entrance of oceanic waters into an almost desiccated Mediterranean Basin.

The Serrano and Guerra-Merchán's hypothesis also invokes peculiar climatic conditions at the time of LM 3 "with a positive hydrological budget (rainfall + runoff > evaporation), contrary to the present-day one", plus restricted water exchanges through the Gibraltar Strait that together might have led to water stratification (Guerra-Merchán et al., 2014). However, an abundant pollen documentation shows that the southwestern Mediterranean climate was significantly warmer and drier than today prior to the MSC, during its first step (as defined by Clauzon et al., 1996) and immediately after the MSC that includes the LM 3 event (Fauquette et al., 2006; Jiménez-Moreno et al., 2010; Feddi et al., 2011). The regional documentation is now completed in deep sea cores (DSDP – ODP Sites 134, 976, and 978) by the record of the three successive LM events (Clauzon et al., 2005) which occurred in the same warm and dry climatic conditions (Popescu et al., submitted). The pollen content of our sample 6 from the Río Mendelín Lago Mare (Do Couto et al., 2014: figure 3), characterized by 56% of herbs including subdesertic plants, locally confirms these climatic conditions. Increased runoff and subsequent water stratification (i.e., anoxic conditions on the sea floor) must result in abundant amorphous organic matter in the palynological slides (Suc et al., 2010), a phenomenon that we did not observe in the Alboran Sea. These data contradict the Serrano and Guerra-Merchán's climatic hypothesis. Thus, the assumption of the Lago Mare being a dilution event as concluded by Rouchy and Caruso, 2006 is not supported.

2. Tectonic versus eustatism

Serrano and Guerra-Merchán argue that tectonics may have played a major role in the stratigraphic succession observed at the Río Mendelín section. We agree that tectonics was active between the deposition of the Lago Mare and the subsequent yellowish clays (Do Couto et al., 2013: figure 3) as attested by the occurrence of syn-sedimentary normal faults. However the authors assumed that "tectonics could have played a more radical role at the end of the Messinian" (Guerra-Merchán et al., 2010). This is an old debate to which we are often

confronted regarding the post-MSC sedimentation. Actually, the debate concerns the respective influence of the sea-level change, with outstanding amplitude in our opinion, and the tectonic activity. Regarding this, two main points must be considered:

- a local view of the MSC, particularly in a very active tectonic area such as the Gibraltar arc, leads to consider the effects of tectonics prevailing over those of eustatism. However, at the Mediterranean scale, the widespread occurrence of post-MSC Gilbert-type fan deltas observed on all types of margins, whether active or passive (Bache et al., 2012) forces to incline towards a generalized response to this unique event, without neglecting the local syn- or post-sedimentary tectonics;
- the sea-level fall and rise opening and closing the MSC are estimated between 1000 and 1500 m (Bache et al., 2012; Gargani et al., 2014) which, in a very short time (140 kyrs; Bache et al., 2012), is more than one order of magnitude larger than the maximum tectonic uplift estimated in the studied area for a significantly longer time (e.g. 100 m; Guerra-Merchán et al., 2014).

3. Post-MSC Gilbert-type fan deltas

Without repeating the arguments in favour of two coalescing Gilbert-type fan deltas at El Túnel and Río Mendelín already detailed in Do Couto et al. (2014), we now focus on four items questioned by Serrano and Guerra-Merchán:

- according to the ages indicated by the calcareous nannoflora, there is no reason to envisage a polyphased erosional surface in which the Gilbert-type fan deltas are nested. This is actually the Messinian Erosional Surface as now accepted by Serrano and Guerra-Merchán;
- the record of the calcareous nannofossil species *Triquetrorhabdulus rugosus* without *Ceratolithus acutus* at El Túnel suggests that these deltaic sediments are older than those at Río Mendelín where these species have been recorded together (Raffi et al., 2006), i.e. sample 5 (Do Couto et al., 2014: table 1);
- the thin iron-rich horizons in the Río Mendelín section, considered as “hard-ground surfaces” in relation with tectonic movements, are very common concentrated horizons in the bottomset beds of the post-MSC Gilbert-type fan deltas, more unsurprising with respect to the sierras as a source in the hinterland;
- whereas Serrano and Guerra-Merchán attribute the conglomerates topping the Río Mendelín section to “post-Zanclean probably Upper Pleistocene (Tyrrhenian)” age, there is in fact no datation contradicting our ascription to the topset beds of the Gilbert-type fan delta.

4. Conclusion

We mainly reiterate the conclusions of the Do Couto et al. (2014)’s paper, particularly concerning the full marine context of the Lago Mare deposit at Río Mendelín which immediately overlies the Messinian Erosional Surface and belongs to a Gilbert-type fan delta. This Lago Mare episode is the LM 3 defined by Clauzon et al. (2005) which immediately followed the brutal marine reflooding of the Mediterranean Basin, that momentarily allowed connection between the Mediterranean Sea and Dacic Bassin (Popescu et al., 2009; Bache et al., 2012).

We appreciate the agreement of Serrano and Guerra-Merchán on some of these major points and we thank them to have offered us the opportunity to reassert our interpretations such as the LM 3 is not a “transitional unit towards normal marine conditions” but was deposited in a full marine context. Some minor items depend on interpretation, such as (1) the two Lago

Mare sequences for Serrano and Guerra-Merchán that we consider the prograding passage from foreset to bottomset beds, or (2) the origin of the erosional contact between the Lago Mare deposits and the Zanclean ones referred by Serrano and Guerra-Merchán to a sea-level fall and to submarine gravity instability by us.

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